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remarks that he is not in agreement with Guyer in regard to the accessory. Guyer refers to this matter as only a "slight discrepancy" but to my own way of thinking, it is the only evidence (in default of better evidence, unfortunately) on which we can at present judge concerning the nature of these bodies that Guyer identifies as the sex chromosomes. Irrespective, therefore, of whether Guyer is right or wrong, it still seems to me that Montgomery's statements can not properly be said to be like those of Guyer except for a "slight discrepancy."

It may be invidious to point out here that the kind of evidence that Guyer admits in favor of the two chromosomes in man being sex chromosomes is of the same sort as the evidence that he has brought forward for similar bodies in birds. The recent thoroughgoing analysis of Pearl and Boring has made apparent that this kind of evidence is in itself inconclusive and unconvincing. The experimental evidence indicates very strongly that in birds the female is heterozygous for a sex factor.

There is another and not unimportant difference between Guyer and Montgomery. Guyer states that a second pairing of the ordinary chromosomes takes place in man. Montgomery says:

I have seen no evidence of any kind of such a pairing of chromosomes in the secondary spermatocytes, neither in my own material nor in that received from Guyer, though I have examined fully two hundred division stages of these cases.

While the second point does not bear directly on the "disagreement" in regard to the sex chromosomes, it raises a doubt as to the value of material that can lead to such diametrically opposed results, for the conflicting statements relate to the same identical preparations.

In order that no misunderstanding may arise I may add that I am entirely in sympathy with the view that in the human race the male is heterozygous in a sex factor; for the experimental evidence relating to sex-linked inheritance strongly indicates that this is the case.

It is with great interest I note in the last paragraph of Guyer's paper a hint (or is it

intended as an announcement?) that the white man has more chromosomes than the negro—a point of view I mentioned¹ in the book under discussion as a possible way of harmonizing Guyer's results with those of v. Winiwarter. If the suggestion is established, some revision may be necessary concerning the Mendelian expectation for the inheritance of skin color in the black-white cross.

T. H. MORGAN

SCIENTIFIC BOOKS

INTRODUCTION TO THE NEW STATISTICS WITH SPECIAL REFERENCE TO THE NEEDS OF BIOLOGISTS

THE number of guides to modern statistical methods consequent upon the realization that mathematical analysis is necessary for the full interpretation of series of observations is now so large that it may be helpful to the beginner to point out some of their chief features.

While Francis Galton's "Hereditary Genius" of 1869 shows the influence of the work of Quetelet, his "Natural Inheritance" of 1889 is probably the first book published in which the modern student can find any consistent comprehensive explanation of the statistical methods as applied to biological problems. While this classic should be familiar to every statistician, it is not suitable as a guide to the beginner, for the formulæ there described have been replaced by those better suited to the practical routine of calculation.

Among the earlier treatises on the new statistics—speaking now of introductions and guides, not of original work—may be mentioned those of Duncker¹ and Davenport² written from the standpoint of methods and the volume of Vernon³ prepared more as a

¹ First suggested in 1912 by Guthertz but rejected by him.

² Duncker, G., "Die Methode der Variationsstatistik," *Archiv. f. Entwicklungsmechanik d. Organismen*, Vol. VIII, pp. 112-183, 1899.

³ Davenport, C. B., "Statistical Methods with Special Reference to Biological Variation," New York, 1899, second ed., 1909.

³ Vernon, H. M., "Variation in Animals and Plants," New York, 1903.

summary of progress in the study of variation, but giving some elementary explanations of methods.

Of more recent works those of the greatest value have appeared in the English language. It would have been too much to expect that the influence of the newer work would extend as far as Madrid and affect the "*Tratado Elemental de Estadística*" of Menguez y Vicente (1907) but something better might have been expected of France and Germany. How backward they are can be seen from such essays as Žizěk's "*Soziologie und Statistik*," München und Leipzig, 1911, or those in the "*Festschrift*" for Georg von Mayr, "*Die Statistik in Deutschland nach ihrem heutigen Stand*," München und Berlin, 1911. Such works as F. Faure's "*Elements de Statistique*" and Maciejewski's "*Nouveau Fondements de la Theorie de la Statistique*" (1911) have, in spite of their attractive titles, no practical value to the biologist—or, as far as the present reviewer can see, to any one else. Nor can anything be said in favor of Al. Kauffmann's "*Theorie und Methoden der Statistik*," just published (Tübingen, 1913).

Forscher's recent book⁴ seems to be a serious attempt, apparently done in almost complete ignorance or with all but a total disregard of the fundamental calculus of the English school, to obtain a better theoretical (mathematical) basis for statistical formulæ. Of the soundness of the mathematical work, I am not able to judge; nor does it particularly concern us here, for practically—that is, as a tool for the man grappling with practical statistical problems—the work has little immediate value.

Turn now to introductory works which may be of value to the beginner.

Many biologists and others are very deeply indebted to the sections on Heredity, Selection and Evolution in the second edition of Pearson's "*Grammar of Science*" for their first knowledge of the new methods. The second

edition is out of print, but a third is being issued.

"*The Primer of Statistics*" (London, A. & C. Black, 1909) prepared by the Eldertons at the suggestion of Sir Francis Galton is for the general public rather than for one who hopes to prepare for investigation. King's little book⁵ although containing something of the newer methods is for the social rather than for the biological student and is far too elementary for those who wish to do research work. Elderton's book⁶ not only embodies the actuaries' viewpoint, but presupposes the actuaries' training. Thus as a *first* book it is quite beyond the depth of the average biologist, but if he is working seriously in statistics it is most helpful on his table.

That Eugene Davenport's book⁷ on breeding—with all its points concerning which the doctors in mathematics and the doctors in biology will disagree—is a pretty good introduction for a certain class of readers is perhaps sufficiently established by the influence which it has evidently exerted in our agricultural institutions. One recognizes the scissors and paste nature of the volume, but this characteristic it shares with practically all the other introductions to statistical methods: the compilation is only a little more obvious and the compiler distinctly more honest in the acknowledgment of original sources than is sometimes the case.

Thorndike⁸ several years ago prepared an introduction for the use of psychologists which has recently (1913) been issued in a much-amplified second edition. The work is more elementary and far more verbose than the book by Brown.⁹ For this reason, Thorndike's text

⁵ King, W. I., "*Elements of Statistical Method*," New York, Macmillan, 1912. Cf. SCIENCE, N. S., Vol. 36, p. 519, 1912.

⁶ Elderton, W. P., "*Frequency Curves and Correlation*," London, C. & E. Layton, 1906.

⁷ Davenport, E., "*Principles of Breeding*," with an appendix on Statistical Methods by H. L. Rietz, 1907.

⁸ Thorndike, E. L., "*An Introduction to the Theory of Mental and Social Measurements*," New York, 1904.

⁹ Brown, W., "*The Essentials of Mental Meas-*

⁴ Forscher, H., "*Die Statische Methode als Selbständige Wissenschaft. Eine Einführung in deren Fundamente und Grundzüge*," Leipzig, 1913.

is better as an introductory work for most American students, while Brown's more technical and more comprehensive book is indispensable to those who care to do really serious research. In this connection the work of Urban¹⁰ may also be mentioned.

The most comprehensive text on modern statistics—an introduction to statistical theory rather than a guide to the application of statistical analysis in any particular field—is that of Yule,¹¹ who has brought to his task the training of an assistant in Karl Pearson's laboratory. To all those who must use statistical formulæ without being able to read with ease the fundamental papers—and this comprises all but a handful of the workers—Yule's book is indispensable. The simpler statistical processes are all treated with care and clearness, and with a terseness refreshing after the verbiage of works written from the biological viewpoint. One must commend the careful system of cross reference, which should greatly facilitate the use of the book, and the very complete and annotated bibliography which should inspire the student to study original sources. The student, moreover, should remember that even Mr. Yule's book does not render this unnecessary, for in the text some subjects of great importance are not treated at all. For example, one misses a discussion of Pearson's various types of frequency curves which have been used with such success for the past several years in describing a great variety of phenomena. The classical fourfold correlation method is also omitted. The most flagrant fault of the book is the putting forward of certain measures of association and correlation, which are worthless,¹² but which, because of their simplicity, are likely to be widely used

urements," Cambridge University Press, 1911.

¹⁰ Urban, F. M., "The Application of Statistical Methods to the Problems of Psycho-Physics," Philadelphia, 1908.

¹¹ Yule, G. U., "An Introduction to the Theory of Statistics," London, Chas. Griffen and Co., 1911, 2d edition later.

¹² See Heron, *Biometrika*, Vol. 8, pp. 109–122, 1911; K. Pearson and D. Heron, *Biometrika*, Vol. 9, pp. 159–315, 1913.

by those who prefer ease of calculation to correctness of result.

The guides which are available the beginner must use: but he should know that there is not only no royal road, but as yet no Baedeker, to statistical analysis. Here, as is wont to be the case with text-books, the guides have for the most part been written by men who have not distinguished themselves by exploration into the territory through which they now propose to lead others. The real student will, therefore, be vigilantly skeptical, and will go as far as he is able to the original sources to read and weigh for himself.

Taking the books mentioned in this review as a class, the greatest criticism that can be made is not that there are blunders in statement and misprints in formulæ, but that throughout there is an incautious attitude towards the real difficulties which the student is to encounter, or even a positive assurance that dangers are only apparent. Nothing could be farther from the truth, for in higher statistics innumerable pitfalls surround the investigator. Serious harm has been done by telling the beginner that he need not understand the formulæ to use them. Neither is it necessary for a chemist to understand his reagents! To be sure, most of us have of necessity to work with but little knowledge of the mathematics which lie back of the formulæ, but it is the obvious duty of the student who proposes to use these newer tools of research to learn all that he can concerning the assumptions upon which the formulæ rest in order that he may apply them with intelligence.

Finally, the beginner must realize that it is as impossible to gain a working knowledge of statistical methods from a text-book without experience in the routine of measurement, computation and interpretation as to acquire proficiency as an organic chemist outside the laboratory. It takes years of hard work to make a proficient biometrician—although some have to their own satisfaction qualified for the writing of texts much more easily.

J. ARTHUR HARRIS